

What is claimed is:

1. A nitride semiconductor device, comprising:
- a) a substrate;
 - b) an active layer of a multiple quantum well structure containing $\text{In}_a\text{Ga}_{1-a}\text{N}$ ($0 \leq a < 1$);
 - c) an n-region nitride semiconductor layer structure interposed between said substrate and said active layer;
 - d) a p-type multi-film layer formed on said active layer, said p-type multi-film layer including,
 - a first nitride semiconductor film containing Al,
 - a second nitride semiconductor film having a composition different from that of said first nitride semiconductor film, at least one of said first and second nitride semiconductor films having a p-type impurity;
 - e) a p-type low-doped layer formed on said p-type multi-film layer, having a concentration of the p-type impurity lower than that of said p-type multi-film layer; and
 - f) a p-contact layer formed on said p-type low-doped layer, having a concentration of the p-type impurity higher than that of said p-type multi-film layer.

2. A nitride semiconductor device according to Claim 1, wherein said p-type low-doped layer is made of $\text{Al}_s\text{Ga}_{1-s}\text{N}$ ($0 < s < 0.5$), and said p-type low-doped layer has a composition

ratio of Al less than that of said p-type multi-film layer.

3. A nitride semiconductor device according to Claim 1, wherein said p-type low-doped layer is formed of a multi-film layered structure with layers made of $\text{Al}_s\text{Ga}_{1-s}\text{N}$ ($0 < s < 0.5$), and an average composition ratio of Al of said p-type low-doped layer is less than that of said p-type multi-film layer.

4. A nitride semiconductor device according to Claim 1, wherein the impurity contained within said p-type multi-film layer and said p-contact layer is diffused into said p-type low-doped layer.

5. A nitride semiconductor device according to Claim 1, wherein the concentration of the p-type impurity of said multi-film layer falls within the range of $5 \times 10^{17}/\text{cm}^3$ through $1 \times 10^{21}/\text{cm}^3$.

6. A nitride semiconductor device according to Claim 1, wherein the concentration of the p-type impurity of said low-doped layer is less than $1 \times 10^{19}/\text{cm}^3$.

7. A nitride semiconductor device according to Claim 1, wherein the concentration of the p-type impurity of said p-contact layer falls within the range of $1 \times 10^{18}/\text{cm}^3$ through $5 \times 10^{21}/\text{cm}^3$.

8. A nitride semiconductor device according to Claim 1, wherein said n-region nitride semiconductor layer structure includes an n-region multi-film layer having a lower-film made of undoped nitride semiconductor, a middle-film doped with an n-type impurity, and an upper-film made of undoped nitride semiconductor.

9. A nitride semiconductor device according to Claim 1, wherein said n-region nitride semiconductor layer structure further includes an undoped GaN layer and an n-contact layer containing an n-type impurity, successively formed on said substrate.

10. A nitride semiconductor device according to Claim 9, wherein said n-type first multi-film layer is formed on said n-contact layer, and the total thickness of said undoped GaN layer, said n-contact layer, and said n-type first multi-film layer falls within the range of 2 through 20 μ m.

11. A nitride semiconductor device, comprising:

- a) a substrate;
- b) an active layer of a multiple quantum well structure containing $\text{In}_a\text{Ga}_{1-a}\text{N}$ ($0 \leq a < 1$);
- c) an n-region nitride semiconductor layer structure interposed between said substrate and said active

layer;

d) a p-type single-layered layer formed on said active layer, made of $\text{Al}_b\text{Ga}_{1-b}\text{N}$ ($0 \leq b \leq 1$) containing a p-type impurity;

5 e) a p-type low-doped layer formed on said p-type single-layered layer, having a concentration of the p-type impurity lower than that of said p-type single-layered layer; and

10 f) a p-contact layer formed on said p-type low-doped layer, having a concentration of the p-type impurity higher than that of said p-type single-layered layer.

15 12. A nitride semiconductor device according to Claim 11, wherein said p-type low-doped layer is made of $\text{Al}_s\text{Ga}_{1-s}\text{N}$ ($0 < s < 0.5$), and said p-type low-doped layer has a composition ratio of Al less than that of said p-type single-layered layer.

20 13. A nitride semiconductor device according to Claim 11, wherein said p-type low-doped layer is made of $\text{Al}_s\text{Ga}_{1-s}\text{N}$ ($0 < s < 0.5$), and an average composition ratio of Al of said p-type low-doped layer is less than that of said p-type single-layered layer.

25 14. A nitride semiconductor device according to Claim

11, wherein the impurity contained within said p-type single-layered layer and said p-contact layer is diffused into said p-type low-doped layer.

5 15. A nitride semiconductor device according to Claim 11, wherein the concentration of the p-type impurity of said single-layered layer falls within the range of $5 \times 10^{17}/\text{cm}^3$ through $1 \times 10^{21}/\text{cm}^3$.

10 16. A nitride semiconductor device according to Claim 11, wherein the concentration of the p-type impurity of said low-doped layer is less than $1 \times 10^{19}/\text{cm}^3$.

15 17. A nitride semiconductor device according to Claim 11, wherein the concentration of the p-type impurity of said p-contact layer falls within the range of $1 \times 10^{18}/\text{cm}^3$ through $5 \times 10^{21}/\text{cm}^3$.

20 18. A nitride semiconductor device according to Claim 11, wherein said n-region nitride semiconductor layer structure includes an n-region multi-film layer having a lower-film made of undoped nitride semiconductor, a middle-film doped with an n-type impurity, and an upper-film made of undoped nitride semiconductor.

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19. A nitride semiconductor device according to Claim 11, wherein said n-region nitride semiconductor layer structure further includes an undoped GaN layer and an n-contact layer containing an n-type impurity, successively
5 formed on said substrate.

20. A nitride semiconductor device according to Claim 19, wherein said n-type first multi-film layer is formed on said n-contact layer, and the total thickness of said undoped
10 GaN layer, said n-contact layer, and said n-type first multi-film layer falls within the range of 2 through 20 μ m.

21. A nitride semiconductor device, comprising:

- 15 a) a substrate;
- b) an n-region nitride semiconductor layer structure formed on said substrate;
- c) an active layer of a multiple quantum well structure formed on said n-region nitride semiconductor layer structure;
- 20 d) a first p-type layer formed on said active layer, being made of p-type nitride semiconductor;
- e) a p-contact layer;
- f) a p-type low-doped layer interposed between said active layer and said p-contact layer, wherein said p-type
25 low-doped layer has the p-type impurity concentration that is

minimized to less than $1 \times 10^{19}/\text{cm}^3$ and gradually increases towards the p-contact layer and the first p-type layer.

22. A nitride semiconductor device according to Claim 21, wherein said p-type low-doped layer is made of undoped nitride semiconductor, and the impurity contained within said p-contact layer and said first p-type layer is diffused into said p-type low-doped layer.

23. A nitride semiconductor device according to Claim 22, wherein said p-type low-doped layer has the thickness adjusted so that the minimum of the p-type impurity concentration is less than $1 \times 10^{19}/\text{cm}^3$.

24. A nitride semiconductor device according to Claim 21, wherein said active layer is made of the multiple quantum well structure including at least one layer made of $\text{In}_a\text{Ga}_{1-a}\text{N}$ ($0 \leq a < 1$).

25. A nitride semiconductor device according to Claim 21, wherein said p-type low-doped layer are formed of a multi-film layer by alternately laminating two kinds of films, which have compositions different from each other.

26. A nitride semiconductor device according to Claim

21, wherein said first p-type layer contains Al.

27. A nitride semiconductor device according to Claim 26, wherein said first p-type layer is formed of p-type multi-film layer by laminating a first nitride semiconductor film containing Al and a second nitride semiconductor film having a composition different from that of said first nitride semiconductor film, and at least one of said first and second nitride semiconductor film contains the p-type impurity therein.

28. A nitride semiconductor device according to Claim 26, wherein said p-type low-doped layer is made of GaN.

29. A nitride semiconductor device according to Claim 26, wherein said p-type low-doped layer is made of $\text{Al}_s\text{Ga}_{1-s}\text{N}$ ($0 < s < 0.5$), and said p-type low-doped layer has a composition ratio of Al less than that of said p-type multi-film layer.

30. A nitride semiconductor device according to Claim 26, wherein said p-type low-doped layer is formed of a multi-film layered structure with layers made of $\text{Al}_s\text{Ga}_{1-s}\text{N}$ ($0 < s < 0.5$), and an average composition ratio of Al of said p-type low-doped layer is less than that of said p-type multi-film

layer.

31. A nitride semiconductor device according to Claim 30, wherein said p-type low-doped layer is formed by alternately laminating layers made of $\text{Al}_s\text{Ga}_{1-s}\text{N}$ ($0 < s < 0.5$) and layers made of GaN.

32. A nitride semiconductor device according to Claim 21, wherein said n-region nitride semiconductor layer structure includes an n-region multi-film layer having a lower-film made of undoped nitride semiconductor, a middle-film doped with an n-type impurity, and an upper-film made of undoped nitride semiconductor.

33. A nitride semiconductor device according to Claim 21, wherein said n-region nitride semiconductor layer structure further includes an n-contact layer containing an n-type impurity, and an undoped GaN layer interposed between said substrate and said n-contact layer.

34. A nitride semiconductor device according to Claim 33, wherein said n-type first multi-film layer is formed on said n-contact layer, and the total thickness of the undoped GaN layer, said n-contact layer, and said n-type first multi-film layer falls within the range of 2 through 20 μm .

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